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SINGLE-CHANNEL APPARATUS FOR HIGH-FREQUENCY TELEPHONY

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[Figures are appended.]

This new single-channel apparatus for high-frequency telephony is mainly intended for the consolidation of steel circuits but can also be utilized for the consolidation of copper circuits.

In a steel circuit with conductors 4 mm in diameter, distances of 20 cm between conductors, and under sleet conditions (Θ = 25 mm), the apparatus guarantees a steady telephone contact at a distance of 80 km between intermediate stations, and 90 km between a terminal and intermediate station, or two terminal stations. In a copper circuit the distance between any two neighboring stations can be brought up to 350 km.

A set of single-channel apparatus (terminal or intermediate) consists of equipment essential for receiving one high-frequency and one low-frequency channel. All line and balancing filters which are necessary for joint operation in both channels are assembled on a rack common to all of the equipment.

The voice-frequency channel has a frequency spectrum of 300 - 2,000 cps; the high-frequency channels transmit 2,600 - 5,100 cps in direction A-B, and 6,700 - 9,200 cps in direction B-A. The high-frequency-channel circuit does not transmit the carrier frequency currents to the line. These currents are utilized as control-frequency currents. The control-frequency in direction A-B is 5,400 cps, in direction B-A, 6,400 cps.

Thus, to the line from Station A, side-frequency currents of 2,600 - 5,100 cps and the control-frequency current of 5,400 cps are transmitted; from station B, side-frequency currents of 6,700 - 9,200 cps, and the control-frequency current of 6,400 cps.

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The following equipment is found at each terminal station: a calling device, intended for dispatching calls to the line and to the switchboard, for (1) conversation control of subscribers, (2) negotiations with subscribers, and (3) transmission and reception of currents of measured frequencies; a voice-frequency current generator, used for providing the line with currents of 400, 1,000, and 2,000 cps; a level indicator with an input resistance of 600 and 5,000 ohms for measuring the level of transmission within limits of -2 ÷ +3.3 neper; two milliammeters, to check the value of the tube plate currents; test jacks, serving to isolate separate circuits of the apparatus for testing and for replacing defective circuits; a set of cords with plugs for switching and testing purposes; a set of connecting lines for transferring separate circuits to the measuring section of the line-switching room for testing purposes, and for replacing circuits with similar ones distributed on other panels; a milliammeter for measuring control-frequency current; and a 24/220 volt voltmeter. An intermediate station set has equipment identical with that of a terminal station, with the exception of a voice-frequency generator.

The entire apparatus in every station, as listed, is installed on one rack. Separate units are distributed on two sides of the frame, with the regulators and jacks placed on the front panels, while the tubes are covered.

The apparatus is equipped with tubes of the metallic series 6J7 and 6F6. It is fed from the ordinary station batteries of 220 ± 22 and 24 volts.

The single-channel apparatus has automatic amplification regulation, based on resistance changes of the tube of a special pre-amplifier, with changes in the grid bias of this tube. The changing bias results from a special selective amplifier which amplifies only the control-frequency current.

The control-frequency current proceeds from the output of the common amplifier to the input of the selective amplifier, which has a high input resistance. It is amplified here, and then rectified through a cuprous-oxide rectifier. The rectified current is measured with a milliammeter. By means of a potentiometer, connected to the grid of the amplifier tube of the selective amplifier, the magnitude of the rectified current is established equal to 0.3 milliampere.

In order to obtain a sharper characteristic of amplification change relative to change in control-frequency current, the difference between two steady voltages is placed on the grid of the tube of the special pre-amplifier. This voltage difference consists of a positive constant voltage of 16 volts, from a special circuit, which is stabilized by a neon tube fed from the plate battery (the stabilization is needed for maintaining a constant value of positive voltage during fluctuations in the plate voltage), and of a negative voltage received from the amplified and rectified current of the control frequency.

Because of this connection, the grid bias on the tube of the special pre-amplifier, with a fluctuation of the level of the control frequency voltage of ± 0.1 neper, changes in the limits from -5 v to -1 v. Thus, the stage gives either amplification or attenuation. The amplification changes are sufficient to compensate for the attenuation changes on the line, depending on weather conditions: from "winter, dry" to "moderate sleet."

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Besides amplification changes, provision is made for changing the frequency characteristic of the amplitude distortions in the regulating stage. This is possible through connection of an LC resonant circuit in a feedback circuit of the special pre-amplifier tube.

With slight attenuation on the line, the bias on the grid of the pre-amplifier increases. In comparison with the input resistance of the LC circuit, the internal resistance of the tube increases also. Consequently, the current feedback, through decrease of the alternating voltage on the LC circuit, drops abruptly. Therefore, practically, one can call the frequency characteristic of the stage linear.

If the attenuation on the line increases, the bias on the grid of the tube decreases. The tube starts to work on the linear portion of the characteristic, its resistance sharply diminishes, and becomes proportional to the resistance of the LC circuit. Consequently, the resistance of the LC circuit becomes significant in comparison to the resistance of the tube and the influence of the feedback on the amplification of the tube increases.

The parameters of the LC circuit are selected in such a way that high frequencies are amplified more by the pre-amplifier than the low frequencies. As a result, the supplementary frequency distortions and line attenuation are compensated for through the distortion and increase of amplification of the special pre-amplifier.

In order to get this adjustment it is necessary, during winter weather, to set the plate current of the tube of the pre-amplifier within the limits of 0.1 - 0.2 ma, changing the negative bias on the grid of the tube by a potentiometer.

In case of a defect in the automatic adjustment of the amplification, a provision is made to change over to manual adjustment, in which a filament battery is used for the negative displacement of the characteristic.

A characteristic of the automatic amplification regulation is the large grid-plate transconductance; it is therefore not permissible for the apparatus to transmit large amplitudes of side frequency currents. At amplitudes of more than + 2.5 nepers, the amplitude characteristic at the output of the high-frequency amplifier levels off. Consequently, the level of the control frequency diminishes, the amplification increases, and the bend of the amplitude characteristic becomes even larger. In the course of the above process, the automatic regulation stops working, the amplification rises up to the maximum value and the coupling starts to vibrate. Therefore, it is necessary, when connecting the apparatus for manual adjustment, to measure the amplitude characteristic of the residual attenuation.

In order to weaken the described effects, the apparatus has an amplitude limiter (Figure 1) consisting of a series and a shunting arm. Due to the joint action of both arms, a steady limiter input resistance is obtained nearly independent of the amplitude of the incoming voltage.

The limiter is connected in the transmitting section of the terminal station between the choke-filter and the modulator and has a threshold limit near the level-2 nepers. To change the threshold limit it is possible to connect elongators either before or after the limiter. By increasing the attenuation of the elongators before the limiter and decreasing the attenuation of the elongators after the limiter, the threshold limit decrease; with a decrease in the attenuation of the elongators connected before the limiter, and with an increase in the attenuation of the elongators after the limiter, the threshold limit increases.

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A system is advisable which permits setting up an absolute level of + 2 nepers at the output of the amplifier.

For controlling the threshold limit a rheostat can be used which permits changing the voltage applied to the cuprous-oxide rectifier of the lateral branch of the amplitude limiter. However, it is not advisable to change the voltage within wide limits because the input resistance of the limiter alters greatly during this process.

The installation of a limiter has yet another useful possibility; because of the limiter the influence of insufficiently large "clear" attenuation of the condenser filters K-2, 3 weakens considerably. This is of special importance in phantom-circuit utilization of the apparatus for a two-way group telephone connection.

In order to compensate for the formation of amplitude frequency distortions in the line, quadripole equalizers are employed in the high- and low-frequency channels. These quadripole equalizers have properties which make it possible to establish different correction limits by resoldering only the real resistances, without changing the reactive elements of the quadripole, even when the apparatus is switched from steel to copper circuits. This characteristic simplifies considerably the quadripole equalizing scheme and facilitates their manufacture. If the apparatus is working on short sections of line, additional links are connected to lengthen the line. Every apparatus has two of these links.

In the feedback circuit of a low-frequency amplifier there are special circuits which make it possible to regulate the frequency characteristics of the channels in high-frequency regions. The regulation makes it possible to compensate for the amplitude distortions of the filters within the limits of 0.3 neper for the whole coupling.

Regulation is also provided in the feedback circuit of the low-frequency amplifier for changing the frequency characteristic of low frequencies (300 cps) in the high-frequency channel. In the voice-frequency channel a similar regulation is carried out by means of a condenser, with a shunt resistance, connected in series with the primary winding of the grid transformer.

Figure 2 shows a skeleton diagram of the terminal station. The scheme permits duplex operation, two-wire and four-wire (phantom) transit connection and a two-way group connection on the high-frequency channel; also duplex operation and two-wire transit connection on the voice-frequency channel.

The skeleton diagram of an intermediate station is shown on Figure 3. One can see that the introduction of special equalizers in the intermediate stations to compensate for the amplitude distortions of the filters makes it possible to obtain good-quality high-frequency channels. Choke filters, D-10, which exclude frequencies above 10,000 cps, are set up to protect the high-frequency channel from influence of other networks.

Figure 4 shows orientation diagrams of equalizers in basic units of the terminal and intermediate apparatus, connected in a steel circuit at distances of 80 km, under "dry, winter -20° C" conditions.

Curves of residual attenuations of high- and low-frequency channels are shown in Figures 5 and 6. The high-frequency channel has a width of 300-2,600 cps, with distortions much less than the permitted standard; the audibility is very good.

The width of the voice-frequency channel is 300 - 2,000 cps. The distortions are also minor, but greater than in the high-frequency channel. The limitation of the higher frequency range diminishes to some extent the transmission quality. Regulation of this channel is by far more complicated than the regulation of the high-frequency channel.

Figure 7 depicts the amplitude characteristics of the high- and voice-frequency channels. The amplitude characteristic of the high-frequency channel was taken while the limiter was disconnected. If the limiter is connected, the curve characteristic changes abruptly, but the influence of the "clear" attenuation of the K-2,3 filters diminishes considerably.

The "clear factor" of channels with the limiter connected fluctuates between 5 - 6 percent, but diminishes to 1.5 percent without the limiter.

From the curves, illustrated by Figures 8 and 9, one can see that during current variations in the tube of the special pre-amplifier not only does the amplification of the stage change, but also the amplitude distortions computed to compensate for distortion on an 80-kilometer - long-section of the steel circuit, in the case of weather change from "winter, dry" to "sleet." On shorter sections of a steel circuit or during operation on a copper circuit, it is possible to find the most advantageous point with wide regulation limits by regulating the plate current of the pre-amplifier tube.

Cross-talk attenuation between high- and low-frequency channels exceeds 7.5 nep. However, by sending induced current along the voice-frequency channel, an audible effect is noticeable in the high-frequency channel in the form of an initial click and a weak background.

Because of its operational characteristics, the apparatus of a single-channel consolidated system is very flexible and can be serviced completely without any additional test equipment. The apparatus is compact and therefore can be set up in a smaller space, which is of special importance in district centers.

Good operational qualities of the apparatus are basic reasons to expect widespread circulation at junctions of regional importance. Mass production of the apparatus will sharply increase the quality of interregional connections and the connections of regions with provincial centers.

/Figures follow./

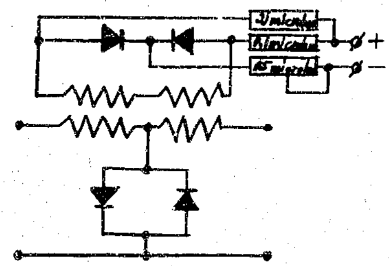

Figure 1. Amplitude Limiter

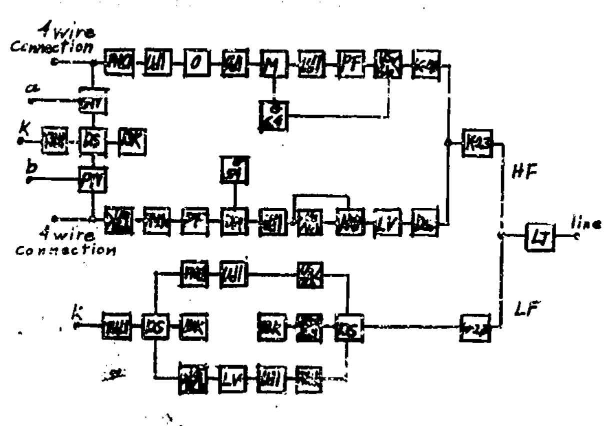

Figure 2. Skeleton Diagram of the Terminal

Station B; DS - differential system, GTV - tone-call generator, BK - balancing circuit, PTV - tho-call receiver, TURI - transit elongator, FKCh - low-frequency filter, O - limiter, M - modulator, PF - band filter, G - oscillator, UsVCh - high-frequency amplifier, UsNCh - low-frequency amplifier of the high-frequency channel, K - condenser filter, LT - line transformer, D - choke filter, LV - line equalizer, ARU - automatic level regulator, DM - demodulator, BDK - balancing choke-condenser filter, UsTCh -amplifier for voice-frequency channel, UdI - elongator.

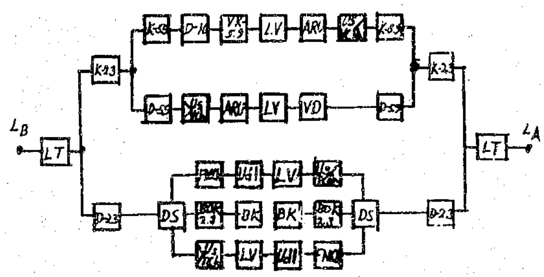

Figure 3. Skeleton Diagram of an Intermediate Station:

DS - differential system, BK - balancing circuit, FNCh - low-frequency filter, UsVCh - high-frequency amplifier, UsNCh - voice-frequency amplifier K - condenser filter LT - line transformer, D - choking filter, LV - line equalizer, ARU - automatic level regulator, BDK - balancing choke-condenser filter, VK - equalizer for the condenser-filters, VD - equalizer for the choke-filters, UdI - elongator.

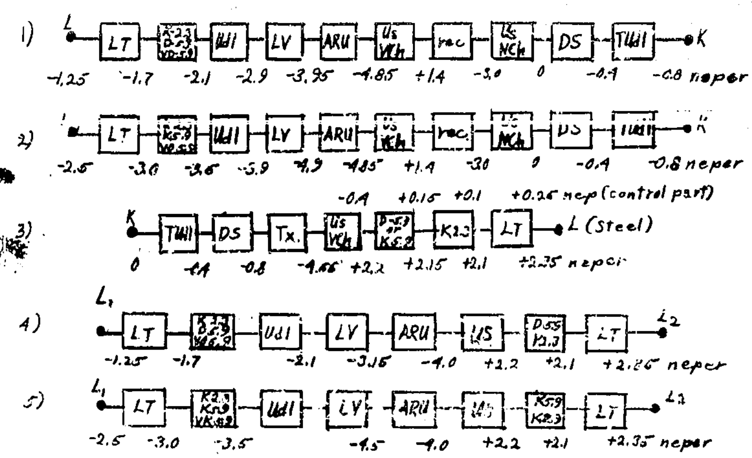

Figure 4. Diagram of Equalizers:

1 - terminal station B (receiving), 2 - terminal station A (receiving), 3 - terminal stations A and B (transmission), 4 - intermediate station (direction A - B, 5 intermediate station (direction B - A.)

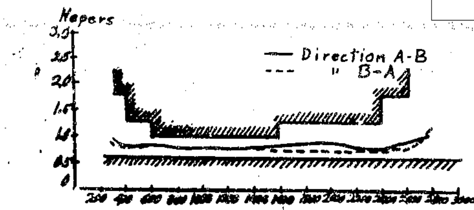

Figure 5. Curve of Residual Attenuation of the High-Frequency Channel

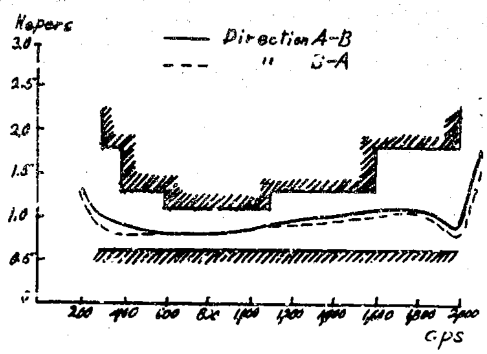

Figure 6. Curve of Residual Attenuation of the Voice-Frequency Channel

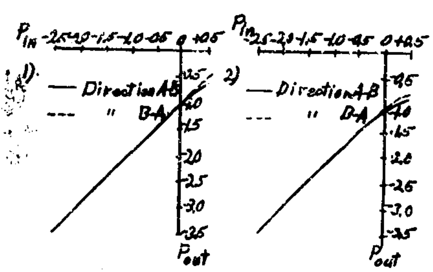

Figure 7. Amplitude characteristics: 1-characteristic of high frequency channel, 2-characteristic of voice frequency channel.

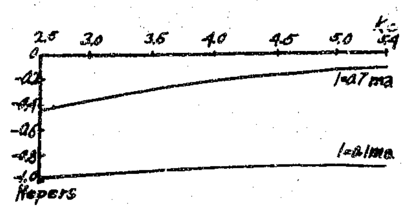

Figure 8. Curve of Attenuation Change in Level Regulation (direction A - B)

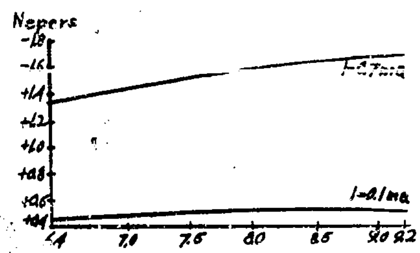

Figure 9. Curve of Amplification Change in Level Regulation (direction B - A)

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